The Role of Posture Learning in Chords with Two Experienced Hands

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Abstract

This study examines the role of posture learning or learning based on a spatial representation of chords. Participants learned left-hand and right-hand chords in seven practice blocks consisting of 180 trials each (two 2-key chords, two 3-key chords, and one 4-key chord). In a test block, participants were confronted with the practised and mirror versions of the chords as well as novel chords they had not encountered earlier to compare the RT. Based on previous research, it was hypothesised that the transfer to the other hand works by hand posture learning or spatial representation. The results were insignificant, so both hypotheses were rejected.

Introduction

The ability to learn is one of the main predictors of socioeconomic status and health (Miech & Hauser, 2001; Walsh et al., 2019). Due to learning, we can adapt to and change our environment. It is a central aspect of everyday life, happening explicitly and implicitly. Learning is associated with several health benefits. More recently, a meta-analysis by Walsh et al. (2019) suggested that learning musical instruments specifically can reduce the occurrence and onset of cognitive impairment, including dementia, drastically. In light of the rising figures of dementia cases, projecting half a million more cases by 2040 in the Netherlands only (Alzheimer Nederland, 2021), more research is needed regarding the mechanisms that play a role when acquiring music skills.

Most musical pieces rely on performing chords. Chords can be played with string, brass, woodwind, and keyboard instruments. They are usually created by depressing several specific keys simultaneously and are part of more complex scores. There are different ways to understand which chord needs to be played, e.g. by absolute pitch, reading a type of notation like the typical five-line staff notation, or by using digital screens that indicate which key needs to be depressed. In a famous experiment by Seibel (1962), participants had to lay down their fingers on electronic keys and depress their fingers as indicated on a screen. Therefore, no special skills or previous knowledge were needed. Response time (RT) and errors were measured over a time interval of a few months. Since that experiment, researchers gathered insights supporting the hypothesis that chord learning is based on a spatial representation as well as learned by hand postures (MacKenzie, 1985; Sanes et al., 1995).

Seibel’s (1962) experiment aimed to determine how RT changes with practice by comparing the improvement of 2-finger or more-finger chords. After extensive practice with three participants, his results suggest that chord learning is based on a spatial representation since the RT was still longer for more-finger chords than for 2-finger chords. However, new research by Agur and Dalley (2009) showed that hand postures in chording are more likely controlled by the motor cortex instead. The primary motor cortex (M1) presumably plays a more significant role in chord learning. Insights from neuroscience support the notion that finger movements are managed by M1 (Schieber & Poliakov, 1998).

In addition to testing the spatial chord hypothesis and posture learning hypothesis, Verwey (2023) tested whether participants would be more aware of the chords they pressed after 240 trials. Unlike in a previous experiment by Hazeltine et al. (2007), participants showed considerable chord knowledge after practising chords (Verwey, 2023).

Another finding of the study by Verwey (2023) was that bimanual chord production, meaning a chord produced by two hands, was faster produced than an unimanual chord produced by one hand only. Verwey's study (2023) supported the notion that practising with two hands simultaneously produces a bimanual coordination skill. This aligns with previous research by Hazeltine et al. (2007), who tested for a bimanual chord representation.

The study from Verwey (2023) compared two groups, a one-hand and a two-hand group, to find out about bimanual chord production. A Chord Complexity Index (CCI) was developed to assess inter-finger interference since biomechanical and neural factors could influence results. For example, the middle and ring fingers have a smaller independent range of movement, causing potentially longer RTs. More inference between neighbouring fingers seemed indeed to be responsible for longer RT (Verwey, 2023).

Following up on the finding of a bimanual coordination skill, focusing more on this bimanual chord learning and production might be interesting. In the experiment from Verwey (2023), the RT for producing the mirror version of a chord after practice was shorter than for a random, novel chord. This finding suggests that participants learned a hand posture with one hand but that the other hand could benefit partially from the representation as well.

Present study

To better understand chord learning and how the brain uses the learned representations for chord production, this research explores the transfer to the other hand of a learned chord by presenting them with mirrored and practised chords. This research involves practising both hands simultaneously in the chord learning process and simultaneous mirroring in the chord mirroring task (see Figure 1). By letting participants practise both hands simultaneously, more insights can be gained on chord learning.

Figure 1

Representation of an example chord of the chord mirroring task.

Note. Depressed fingers are presented with an underlined number. The right hand performs a mirrored version of the left-hand chord and vice versa. Thumb = 1, index finger = 2, middle finger = 3, ring finger = 4, and pinkie = 5.

The Participants get to practise two 2-key chords, two 3-key chords, and one 4-key chord with one hand during the seven practice blocks. Afterwards, participants got tested for the originally practised chords, their mirrored version, and new novel chords with the same and other hand. So, the test block consisted of two chord versions for the same and the other hand.

Hypotheses could be tested based on the measured RTs in those test blocks. In total, there were six transfer conditions. Namely the practised chords with the same hand, the mirrored chords with the same hand, the novel chords with the same hand, the practised chords with the reversed hand, the mirrored chords with the reversed hand, and the novel chords with the reversed hand. It can be expected that the RTs are shorter for the practised chords with the same hand than for the other conditions. If the RT is longer for the mirrored versions of the chords with the reversed hand than for new chords from the same complexity, it supports the hypothesis that the transfer to the other hand is based on hand posture learning. This leads to the first hypothesis: The transfer to the other hand is based on hand posture learning.

However, it is also imaginable that a spatial representation plays a more significant role in chord learning and retrieval involving two hands. Then, transferring from the left to the right hand and vice versa should be better with the reversed practice chords. Nevertheless, the production of the mirror version should take longer, approximately as long as the RT for a new novel chord. Following this train of thought, the mirror version of a chord should not be easier to execute than a new chord because the other hand could not use the other hand's learned motor representation. This leads to the second hypothesis: The transfer to the other hand is based on spatial representations.

Method

Participants

Twenty students (M_{age} = 21.56, SD_{age} = 2.50) volunteered or chose to participate in this research to receive points as a compulsory part of their undergraduate degree. One participant had to be excluded for an error rate of more than 35% in the test block. Three others were excluded due to irregularities and mistakes during the experiment itself. Once due to an unknown technical problem that caused wrong key registration and twice due to typos the researcher made when setting up the experiment. Sixteen participants who all received different chord combinations could be included. This was intended so that the results would be counterbalanced.

Students aged 18-35 were allowed to participate. Two men participated and 14 women. 12 participants indicated being right-handed, and 4 participants indicated being left-handed. They all stated that they had not used alcohol or other narcotics 24 hours before the experiment. Moreover, all participants indicated not to smoke regularly, so withdrawal symptoms from nicotine could be excluded as an error source. Finally, they all claimed to possess normal eyesight and did not wear glasses, so visual errors could also be excluded. The ethics committee of the BMS faculty at the University of Twente approved the experiment.

Materials

The experiment took place on the campus of the Universiteit Twente in the BMS lab. The BMS lab consists of rooms that can be video-monitored by researchers. For this research, several different cabins were used. The materials differed slightly with another computer and software version being used; however, this should not have impacted the experiment. One set-up version consisted of a Dell OptiPlex 7050 7th Generation computer running E-Prime® 2.0 PST (Psychology Software Tools, 2023), the other of an HP Z1 Entry Tower computer running E-Prime® 3.0 PST (Psychology Software Tools, 2023). An AOC G2460PF display with a 144 HZ refresh rate and a Razer Huntsman V2 Tenkeyless keyboard were used for all experiments. It should be noted that this particular keyboard was chosen because it relies on optical switches, which results in shorter RTs, and it can recognise several inputs simultaneously.

Figure 2: A participant performs a 2-key chord.

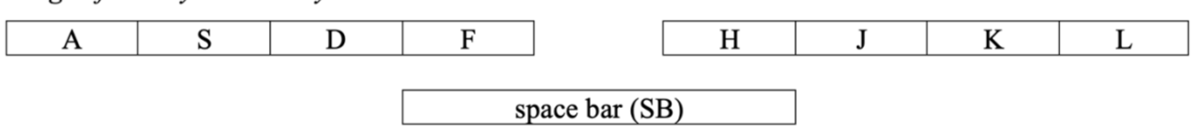
Before the start of the experiment, every participant signed an informed consent (Appendix A). Moreover, further data was gathered using a questionnaire between the practice blocks and test blocks at the end of the experiments (Appendix C). The participants were supposed to denote their gender, age and handedness and were presented with an awareness task. It was asked which chord combinations they could recall. In a second step, it was asked how they recalled the combinations. They were given six options to choose from if they remembered a) the letters, b) the positions of the keys, c) the positions of the squares, d) pressed the keys in their mind, e) pressed the keys on the tabletop or f) if they recalled them differently and if so how. Then, they were asked if, when, how long per week and how many years they played the piano, other instruments (with the actual instruments) and sports (with the actual sports). Finally, they were asked if they stuttered or had dyslexia.

The Task

The experiment consisted of two parts: seven practice blocks and then a test block. This was communicated beforehand to the participants (see Appendix C for the participant's instructions). During the practice blocks, the participants learned to execute the chords. The participants had to hold their fingers above or on the keys A, S, D, F, and the space bar (SB) with their left hand and above or on the keys SB, H, J, K, and L with their right hand (see Figure 2). Then, they were supposed to simultaneously press several keys that were indicated in cyan on display with either their left or right hand and with the specific fingers for the specific keys. If it was a left-hand chord, the left thumb was supposed to be used for the SB and vice versa. If they pressed the correct keys simultaneously, the cyan keys fainted grey and were followed by the next chord. Otherwise, an error message was put out by the system. After each block, there was a break of four minutes. Five chords were practised per participant: two two-key chords, two 3-key chords, and one 4-key chord. Every chord was practised 36 times in each of the seven practice blocks, resulting in 180 trials per block.

Figure 3

Image of the keys on the keyboard



In the last block, the test block, the participants were confronted with six different conditions. They were presented with the five chords they already practised before, their mirror version, and five novel chords they had not practised before for the same and reversed hand. The results were counterbalanced, meaning all participants received different chords so that potential confounding variables stemming from enslavement or other biomechanical or cognitive influences could be excluded as an error source.

Procedure

Before the start of the experiment, the participants signed an informed consent (Appendix A) and received the participants' instructions (Appendix B). They had to store their electronic devices outside of the room to prevent potential distractions. The participants received the questionnaire between the practice and final test blocks (Appendix C). The experiment took, on average, a little less than three hours. After the final test blocks, the participants were free to leave and received three SONA points. Those who volunteered received a chocolate bar to express gratitude for their participation.

Data analysis

Before further analyses, the gathered files were pre-screened on error rate. Using the statistical software R version 4.3.2 GUI 1.80 Big Sur ARM build (8281) together with RStudio version 2023.09.1+494 using mainly the additional packages afex, AICcmodavg, broom, dplyr, emmeans, extrafont, ggplot2, ggpubr, readxl, and tidyverse. The error proportions in the practice and test blocks were transformed into the arcsine form suitable for an ANOVA. Boxplots were created to visualise the RTs and error proportions for the practice and test blocks.

Moreover, ANOVAs were conducted. First, an ANOVA with RT as the dependent variable and seven blocks x three chord types (2-key-, 3-key-, and 4-key-chords) x two hand groups (the allocation if participants receive the LR version of the experiment or the RL version so that the whole experiment would be mirrored for them and the results counterbalanced) as independent variables with hand group as a between-subjects variable. The same ANOVA design was used with arcsine transformed error proportions as the dependent variable as well.

Third, an ANOVA with RT as the dependent variable and six test conditions x three chord types (2-key-, 3-key-, and 4-key-chords) x two hand groups as independent variables with hand group as a between-subjects variable was carried out. The same ANOVA design was also used with error proportion as the dependent variable.

Chords were considered to be pressed simultaneously when the timing difference between the fingers was less than 50 ms. Moreover, statistical significance was assumed with a p-value under $\alpha = 0.05$. Lastly, The p values of the F tests were corrected for sphericity using the Greenhouse–Geisser correction when the Mauchley tests for sphericity were significant.

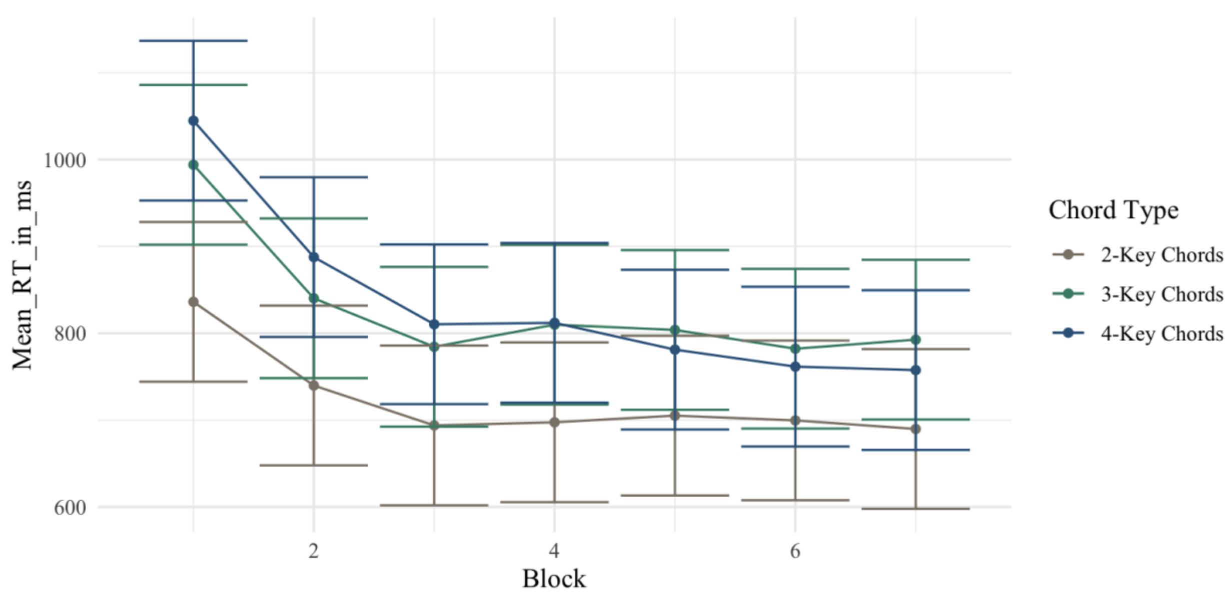
Results

Practise Phase

The RT for every block in the practise phase was calculated using the participants' mean RT of the trials pressed correctly. For an overview of the mean RT of all 16 participants per block, see Figure 4.

Figure 4

Line chart of the mean RTs in the practice blocks.



An analysis of variance was conducted on the mean response time with a 2 (Hand Group) × 3 (Chord Type) × 7 (Block) design with Hand Group as the between-subject variable.

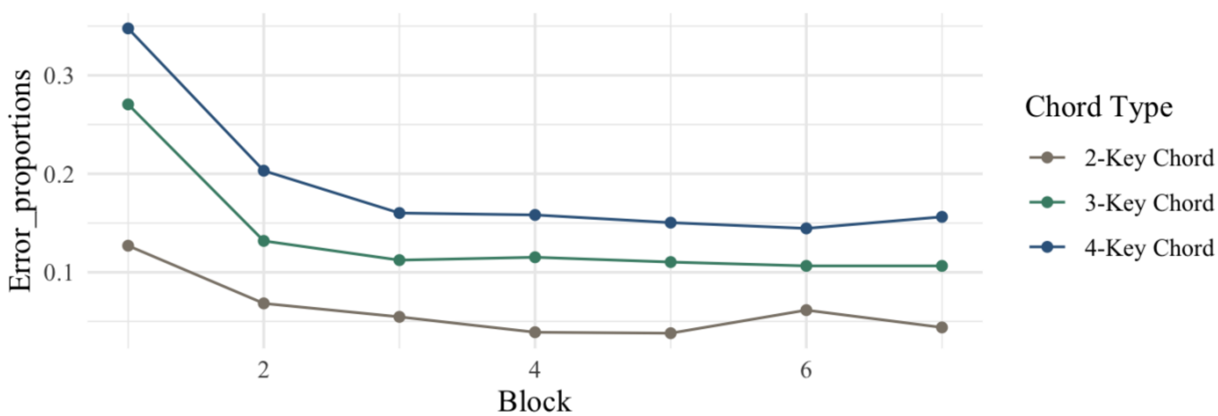
The ANOVA indicated a main effect of Chord Type (the three different chord types with 2-key-, 3-key-, and 4-key-chords), Chord Type $F(2,28)=5.60$, $p=.017$, $\eta p2 =.29$. Furthermore, a main effect of Block was found, Block $F(6,84)=12.32$, $p<.001$, $\eta p2 =.47$. Other main effects and interactions turned out to be insignificant.

Moreover, the mean error proportion in each block was analysed and is depicted in Figure 5. The same analysis of variance as on the RTs was conducted on the arcsine transformed error proportion with a 2 (Hand Group) × 3 (Chord Type) × 7 (Block) design with Hand Group as the between-subject variable.

The ANOVA showed a main effect of Chord Type (2-key-, 3-key-, and 4-key-chords), Chord Type $F(2,28)=6.55$, $p=.013$, $\eta p2 =.32$. Moreover, it showed a main effect of Block, Block $F(2,28)=13.60$, $p<.001$, $\eta p2 =.49$. Visualised in Figure 5, the error proportion decreased with the number of practice blocks. It increased significantly with the number of fingers used.

Figure 5

Line chart of the mean error proportion per chord type in the practice blocks

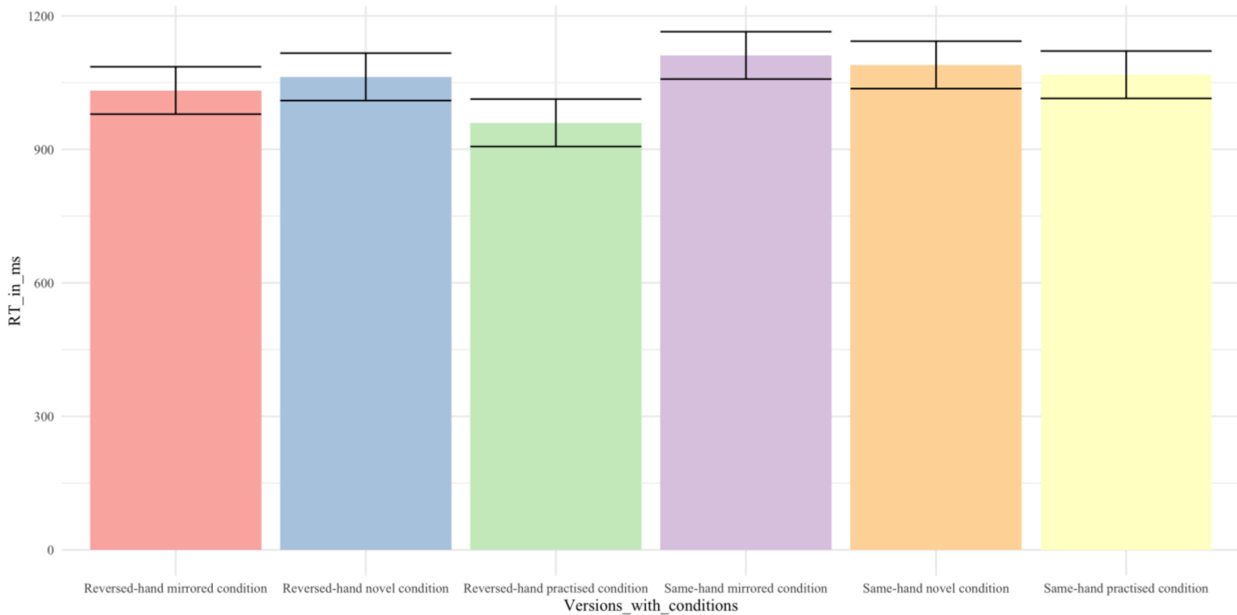


Test Phase

The last block, the test block, was analysed separately. In this block, the three different chord versions were performed by each hand. The mean RTs are displayed as a dumbbell chart in Figure 6, contrasting the RT from the same hand condition and the reversed hand condition.

Figure 6

Bar chart of the mean RT in the three test conditions.



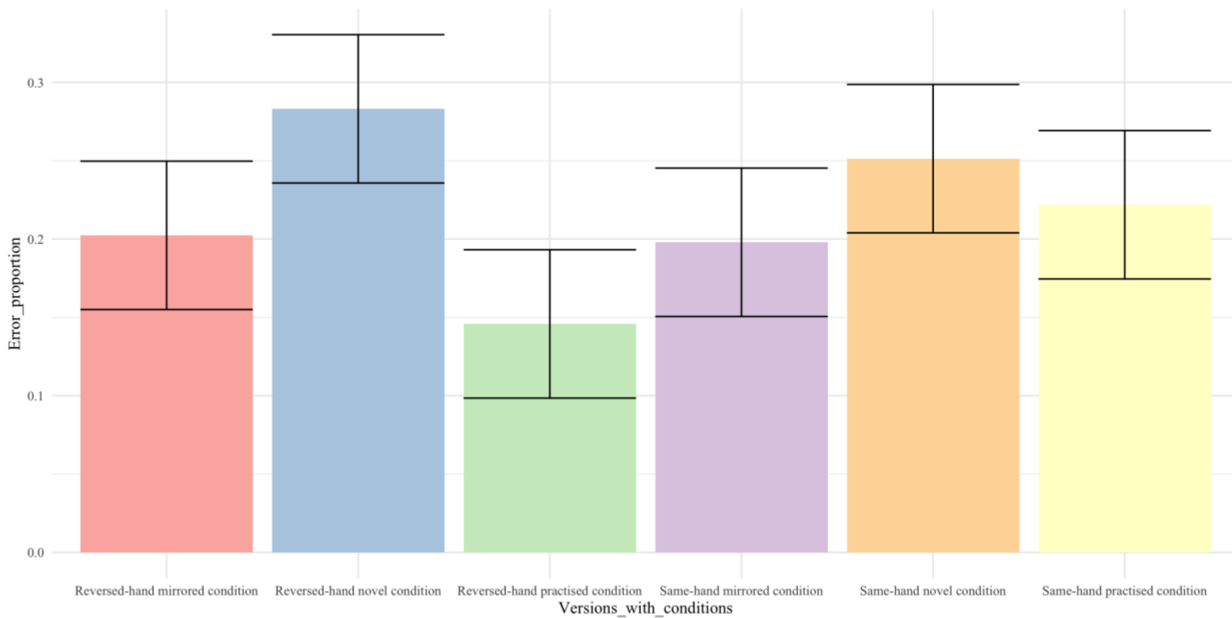
An analysis of variance was conducted on the mean response time with a 2 (Hand Group) × 2 (Hand Used) × 3 (Chord Version) × 3 (Chord Type) design with hand group as the between-subject variable.

The ANOVA showed a main effect of the hand that was used (same hand or reversed hand), Hand Used $F(1,14)=4.75$, $p=.047$ $\eta p2 =.62$. Moreover, a main effect of the chord type (2-Key chords, 3-key chords, 4-key chords) was found, $F(2,28)=23.06$, $p<.001$ $\eta p2 =.62$. It turns out that the mean RT for the two-key chords is shortest, followed by the four-key chords and the three-key chords.

Error proportions were calculated as well for the three conditions. They are depicted as a dumbbell chart in Figure 7. The error proportion was smallest in the same-hand-practised condition and highest in the same-hand novel condition, while the other four conditions were closer to each other.

Figure 7

Bar chart of the mean error proportions in the three test conditions.



Finally, an analysis of variance was conducted on the mean error proportion with a 2 (Hand Group) × 2 (Hand Used) × 3 (Chord Version) × 3 (Chord Type) design with hand group as the between-subject variable.

The ANOVA showed a main effect of the chord version (mirrored, novel, or practised), Version F(2,28)=4.24, *p*=.040 ηp2 =.23. Moreover, the ANOVA also indicated a main effect of the chord type (2-Key chords, 3-key chords, 4-key chords), Chord Type F(2,28)=10.92, *p*=.001 ηp2 =.44. Notice that the arcsine transformed error proportions were smallest in the 2-key condition and highest in the 4-key condition.

Awareness Questionnaire

During the practice phase, the participants were confronted with five different chords. They could recall 63% of the chords in the awareness questionnaire between the practice and test block, mainly through the positions of the keys, the squares on the screen and the combination of the letters. In total, 50 out of 80 chords were remembered correctly. Seven out of 16 participants had some experience in playing the piano. Four others played other instruments. Correlation coefficients were calculated between the RT of the mean RT of all practice blocks and the participants' answers in the awareness questionnaire (see Table 1).

A score was designed to correlate the recalled chords of the awareness questionnaires with other variables. For two-key chords, the number of correctly recalled chords was multiplied by two, for three-key chords by three, and with four-key chords by four (a*2+b*3+c*4=x). This score was balanced to consider the chord complexity. Per item (a specific key) that was remembered, one digit was added up.

Table 1

Correlation coefficients between the RT and the participants' answers in the awareness questionnaire.

Variables correlated with RT	**R-value**	**P-value**
Score of the awareness questionnaire	.13	.60
Hours per week of piano	.76	.002
Years of piano	.64	.003
Hours per week of other instruments	.15	.42
Hours per week of sports	.13	.86
Years of sports	.13	.69

Discussion

The present research explored if the transfer of learned chords to the other hand is higher when both hands are as experienced. Therefore, participants practised five counterbalanced chords to avoid biomechanical influences in seven practice blocks. Every participant learned two 2-key chords, two 3-key chords with their left and right hand, and one 4-key chord with either their left or right hand. After 1,260 trials, the participants were tested on three conditions (practised, mirror, novel) with the same and reversed hand.

Results of the ANOVA showed improvements in the RT during the practice blocks, indicating that learning did take place. The most noticeable difference was between block one and block two and between block two and block three. After that, improvements in RT reached a plateau. This leads to the conclusion that after ca. 360 trials, the chords were learned. Moreover, there was a main effect between the chord types. 2-key chords had the shortest RTs; however, even though the RTs were faster for 3-key chords than for 4-key chords in the beginning, this changed after block four. After block four, the RT was shorter for 4-key chords than for 3-key chords. It can be hypothesised that 3-key chords are the more complicated chords in the long run because techniques such as subtracting one finger from the hand might make forming 4-key chords faster.

The analyses of the arcsine transformed error proportions for the practice chords also indicated learning as the error proportions decreased over time. Like the RTs, the improvements in error proportions reached a plateau after block three. This gives additional support to the hypothesis that after ca. 360 trials, the chords were learned. Furthermore, the error proportions differed significantly among the chord types. The error proportions were consistently smallest for 2-key chords, followed by 3-key and 4-key chords. So even though the RTs became longest for 3-key chords after block four, this did not align with the error proportions. It can be theorised that 2-key chords are simply easier, resulting in shorter RTs and smaller error proportions. The more deliberate and active search for 3-key chords might have slowed the chord-forming process but resulted in fewer errors. Four-key chords were formed faster after chords were learned, potentially using the subtracting technique; however, this still resulted in a higher error proportion.

The results of the ANOVA of the test phase showed that the hand that was used had a significant effect. As expected, the RT was the shortest for the practised same-hand condition, displaying that learning affects the RT. For all three conditions, the RT was shorter when the conditions were carried out with the same hand. So even the RT of the (new unpractised) same-hand novel chord was shorter than all conditions with the reversed hand. Remarkably, the RT was longer for the reversed mirror version than for the reversed novel chord version. Even though only the Hand Used variable delivered a significant result, the differences in RTs between the chord versions might contribute to follow-up research questions. The significant differences between the hands suggest that chording skills are hand-specific and that chording knowledge tends to be inflexible. This supports previous research that found chord knowledge is mainly based on the M1 brain regions instead of centralised processing.

Also, the ANOVA on the test phase RTs suggested a main effect of the chord type on the RTs. Interestingly, the mean RTs were shortest for the 2-key versions and the longest, just as for the last practice blocks, for the 3-key versions. This aligns with the hypothesis that 3-key chords might be more difficult than 4-key chords.

The ANOVA of the arcsine transformed error proportions of the test block backs this up. A significant effect of the chord type was found. The highest error proportion mean was found with 3-key chords and the shortest again with 2-key chords. Furthermore, a main effect of the used hand was found. The same-hand condition was significantly more accurate than the reversed one, supporting the construct that chord knowledge is inflexible.

Neither hypothesis could be accepted based on the gathered data and analyses. First, it was hypothesised that the transfer to the other hand is based on hand posture learning. Then, the transfer to the other hand would have been better with mirrored chords relative to new chords, resulting in shorter RTs.

However, participants did not perform significantly better on the mirror chord versions than the other test conditions. The RTs were indeed (insignificantly) better for the same-hand condition than the novel chord. However, the mirror version of the chord was even worse for the reversed-hand condition than the RT of the novel chords. The second hypothesis, that the transfer to the other hand is based on spatial representation, could also be rejected. Based on that hypothesis, the transfer to the other hand would have been better with the same practised chords compared to the novel chords. Again, no significant main effect was found that could support that hypothesis.

The results of this research align with findings from Verwey (2023) mentioned in the introduction. It suggests that chording skills are based on learned postures and not on a spatial representation. The unique design of the present study with two hands involved in the learning process might have overwhelmed the mental capabilities responsible for chord learning so that producing the mirror version of the chord did not result in significantly shorter RTs other than suggested by Verwey (2023) with a different study design. Learning chords simultaneously might result in more rigid and inflexible knowledge that makes the resource less accessible by the other hand.

In addition to running the ANOVAs, the RTs were correlated with answers from the awareness questionnaire. For the Awareness task, a score was thought of that considers the chord complexity. This score was not significantly correlated with the RTs, showing that chord awareness did not play a major role in the RTs. This supports the notion that the motor cortex is more critical in chord learning since chord knowledge is supposedly processed more decentralised. This suggestion aligns with Schieber and Poliakov’s (1998) neurological insight that the M1 brain region essentially controls finger movements.

A significant negative correlation was found between piano skills and playing years. The finding underlines that chord learning is a skill that can improve with practice and that the experiment design is well suited to studying chord learning.

Limitations

The sample size of this research is relatively small, with sixteen participants. The results could be counterbalanced, but outliers might have distorted the results. The experiment took almost three hours, so the attention span may have suffered despite seven four-minute breaks. Furthermore, the research was opened for people with prior chording skills due to a need for more participants. The correlation between playing the piano and the RT is immense, so their participation might have influenced the outcomes. In addition, the sample was a convenient sample consisting of the social environment of the researcher and UT students who had to take part. They might not represent the general population. Lastly, a score was developed to analyse the awareness questionnaire. The score was an attempt to value the memory of more complex chords. However, this score is an arbitrary construct.

Directions for future research

Even though the hypotheses could not be accepted, this research helped to understand better how chords are learned. For replication purposes in future research, a larger sample size is advised, excluding participants with prior piano skills since piano skills are highly correlated with RTs. Moreover, it seems interesting to assess different parameters than simply the reaction time and errors. By using an fMRI, it might be possible to trace down precisely the brain regions that are highly active in the process.

Conclusion

The present study aimed to explore the transfer of chord knowledge from one hand to different versions of the chord on the same hand and the other hand. This research can be distinguished from previous research since both hands were experienced in the final test block. Both hypotheses were rejected since (a) the transfer of the chord knowledge to the other hand was not better with the mirrored version of the chord, and (b) the transfer to the other hand was not significantly better with the same practised chord.

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Appendix A

Consent Form for the study:
'The Role of Posture Learning in Chords with Two Experienced'

YOU WILL BE GIVEN A COPY OF THIS INFORMED CONSENT FORM

Please tick the appropriate boxes	**Yes**	**No**
Taking part in the study		
I have read and understood the study information dated [04/10/2023], or it has been read to me. I have been able to ask questions about the study, and my questions have been answered to my satisfaction.	◻	◻
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	◻	◻
Use of the information in the study		
I understand that the information I provide might be used for further research	◻	◻
I understand that personal information collected about me that can identify me, such as [e.g. my name or where I live], will not be shared beyond the study team.	◻	◻
Consent to be Audio/video monitored.		
I agree to be audio/video monitored. Yes/no	◻	◻

If you have questions about your rights as a research participant, or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the Secretary of the Ethics Committee/domain Humanities & Social Sciences of the Faculty of Behavioural, Management and Social Sciences at the University of Twente by ethicscommittee-hss@utwente.nl

Appendix B

October (2023).

Participant Instruction

You will participate in an experiment to better understand how people learn chording skills, like when playing the piano or a saxophone.

The experiment is composed of 8 blocks. After each part, you have a break of 4 minutes. You can do whatever you want during this break, but we ask you to give your phone to the experimenter to prevent intrusion of the experiment.

It is important for you to react as fast as possible and make fewer errors (try less than 8%!). If you make more errors, the experiment will take you longer to complete.

The instructions will be displayed on the screen. If something needs to be clarified, please ask the experimenter.

The experiment will take about 3 **hours** and will get you 3 **SONA credits**. At the end of the experiment you will be asked to fill in a short survey. Any remarks about the experiment can be made there.

Good luck with the experiment, and thanks for participating!

Malte Hof
Prof. W.B. Verwey

University of Twente

Appendix C

Participant Number ______________________________

Age ______________________________

Gender F / M / NB ______________________________

Right or left-handed ______________________________

Do you smoke? ______________________________

Did you drink alcohol in the last 24 hours? ______________

In this experiment, you reacted by pressing keys after perceiving a stimulus light. There were a number of different combinations, while other combinations did not occur. Are you able to write down the combinations you have been practising? (using the letters ASDF – Space Bar – HJKL)?

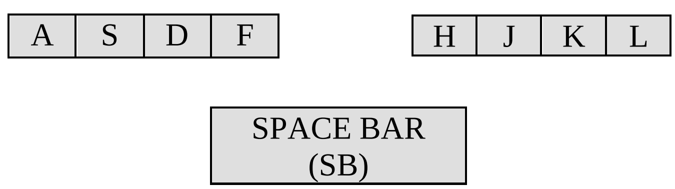

Image of the keys on the keyboard

1) What did you do to determine on the previous page of this survey the keys you pressed? (you may circle more than 1 alternative).

a) I remembered the combination of the letters.
b) I remembered the positions of the keys
c) I remembered the positions of the squares on the screen.
d) I pressed the keys in my mind
e) I pressed the keys on the tabletop.
f) Differently, namely:

Below, a number of activities is mentioned. Do you perform these activities? If yes, how long was it ago, and how long have you done this (check 1 alternative per row). Indicate no at the end of the row if you have never done this activity.

a) Do you play **video games**?

When?	I still play	until 3 years ago	more than 3 years ago
I play(ed)	< 1 hour a week	1-7 hours per week	> 7 hours a week
totally I played …	< 1 year	1-5 years	> 5 years

b) Do you play **the piano?**

When?	I still play	until 3 years ago	more than 3 years ago
I play(ed)	< 1 hour a week	1-7 hours per week	> 7 hours a week
totally I played …	< 1 year	1-5 years	> 5 years

c) Do you play another **musical instrument**(s), if yes, which one(s)?

When?	I still play	until 3 years ago	more than 3 years ago
I play(ed)	< 1 hour a week	1-7 hours per week	> 7 hours a week
totally I played …	< 1 year	1-5 years	> 5 years

d) Do you play any **sport(s)**, and which**?** (in the case of several sports, please answer for each sport separately)

When?	I still play	until 3 years ago	more than 3 years ago

I play(ed)	< 1 hour a week	1-7 hours per week	> 7 hours a week

totally I played …	< 1 year	1-5 years	> 5 years

e) Do you **stutter?**

no	a little	a fair amount	severely

f) Do you have **dyslexia?**

no	a little	a fair amount	severely

3) Do you have any remarks about the experiment?